Mean Kinetic Temperature (MKT) Calculation Should be Real-time

March 22, 2018 - **Shailesh Mangal**

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A change in temperature doesn't determine whether cold chain products spoil.

Rather, it's the 'degree' and 'frequency' of changes in temperature that affect the rate at which cold chain products degrade, and ultimately, spoil.

Figuring out whether these variables affected your shipments will tell you when products are damaged and ought to be disposed, but gauging that in real-time could help you prevent that loss to begin with.

Let's dig into what real-time MKT could mean for your cold chain management and how to calculate it accurately.

Different cold chain products have different levels of sensitivity — and tolerance — to temperature fluctuations.

The difference between a mango ice pop and mush is a single degree.

For more valuable cold chain cargo like vaccines or other food items, that single degree could also be the difference between life and death.

Small temperature deviations could have a big impact. Even if there's not major physical change to a cold chain product that thawed and refroze, its shelf life could have reduced drastically.

The most common way to watch out for such temperature excursions in the cold chain has been through temperature data loggers. In their simplest form, they periodically record the temperature, including the highest (or in some cases, the lowest) that a cold chain shipment experiences, allowing you to gauge what the shipment has been through.

While it sounds simple enough, temperature excursion management for cold chain logistics isn't as straightforward as "if it went over, it's over".

A bag of frozen peas, for instance, will probably survive even if there's a minor temperature excursion or the AC goes off for a brief period while it's being transported. As long as it doesn't thaw and stay outside its ideal storage temperature for too long, it'll be just fine.

A bag of frozen popsicles wouldn't be as lucky though.

Cold chain products that are stored in warehouses or transported often experience temperature excursions, going above or below their acceptable storage temperature ranges.

If crossing temperature thresholds was the only criteria that decided whether a cold chain con-

signment is fit or not, we'd end up wasting a lot more food and medicine than we consumed.

It isn't, and we don't, and fortunately, that doesn't always lead to unfortunate incidents. What that means is infrequent short temperature spikes don't necessarily translate to compromised product quality that's unfit for human consumption.

If cold chain shipments that exceed their temperature thresholds aren't necessarily spoiled, is there a reliable way to determine the degree of spoilage that may have happened without opening and testing samples on the way?

Why yes, there is — by determining its Mean Kinetic Temperature (MKT).

Why Mean Kinetic Temperature?

Regulatory bodies as well as organizations in manufacturing and distribution that deal with temperature-sensitive products are trying to create uniform standards for cold chain monitoring — especially a single temperature that's just right — which ensures the shelf life, quality, and safety of cold chain products while also accommodating inevitable temperature excursions. Temperature variations in cold chain storage and transportation, however, make it difficult to select a single reliable temperature for use in product viability testing.

Averaging out temperature measured over the course of cold chain transport or storage isn't an ideal solution either.

Averaged temperatures don't account for the biochemical or phase change effects that may have caused irreversible changes or defects in the quality of temperature-controlled shipments, even if temperatures are exceeded for a just a short time.

> **The rate of chemical reactions usually doubles with every 10 °C increase in temperature.**

Attempts were made to address this variability by calculating a "virtual temperature".

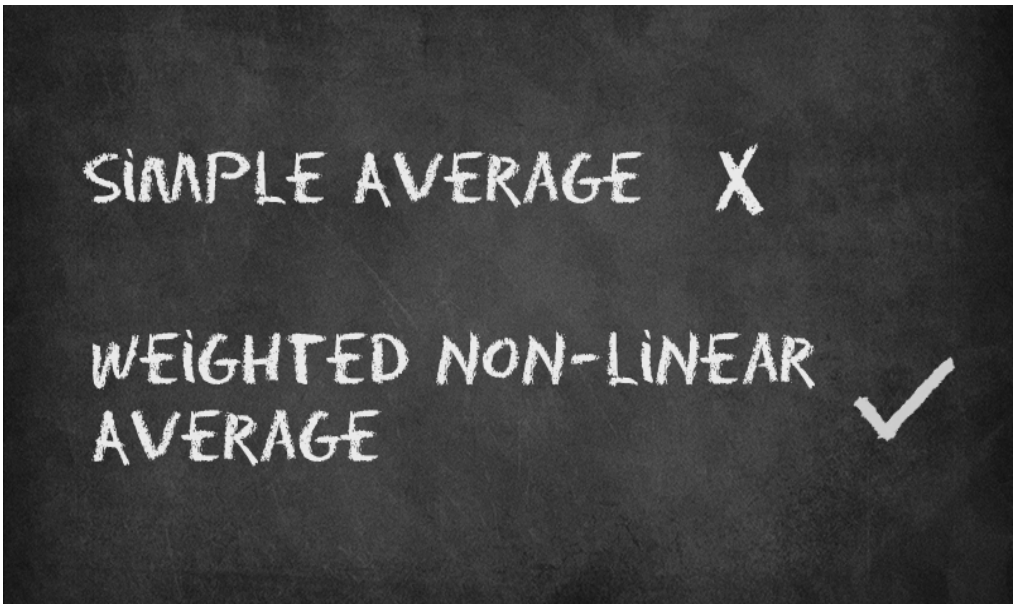
It would consider the expected temperature variability in a given cold chain as well as the acceptable temperature excursions that cold chain products can endure without spoiling. The equations developed to determine such a "virtual temperature" evolved into the Mean Kinetic Temperature (MKT) that's used to represent the impact of temperature variations in cold chain

logistics today.

MKT calculations are more reliable than a simple numerical average or arithmetic mean because it gives more weight to higher temperature excursions, accounting for the time factor and the accelerated rate of thermal degradation at certain temperatures.

> **MKT represents the cumulative thermal stress that a cold chain product experiences, making it a better tool to gauge the impact of temperature excursions in your cold chain distribution and handling.**

What is Mean Kinetic Temperature (MKT)?



Put simply, MKT is a single temperature that accounts for the cumulative effect of numerous temperature variations over a period of time.

It involves complex math to determine a simple temperature "sweet spot" at which your cold chain shipment is most (likely) stable — and your shipment's survival will depend on whether or not it stayed there.

> **MKT is a weighted non-linear average that depicts the effects of varying temperature over time.**

It's a "weighted non-linear" average because simple arithmetic averages normalize spikes that could have caused spoilage, masking mayhem.

MKT goes beyond simply detecting temperature excursions, it allows you to determine the impact of several temperature fluctuations on product quality in cold chains.

MKT helps determine the ideal temperature to maintain during cold chain operations such as:

- Production/manufacturing
- Packaging/repackaging
- Handling
- Distribution
- Warehousing

While there's no global consensus on whether MKT is the best measure of the effect of temperature excursions during cold chain transportation and shipping, MKT is an important tool in shipment stability testing today, especially for extremely temperature-sensitive shipments like pharmaceuticals or vaccines.

How is Mean Kinetic Temperature (MKT) Calculated?

It involves some complex math. Here is the formula to calculate MKT:

$$T_K = \frac{\frac{-\Delta H}{R}}{ln\left(\frac{e^{-\frac{\Delta H}{RT_1}} + e^{-\frac{\Delta H}{RT_2}} + \cdots + e^{-\frac{\Delta H}{RT_n}}}{n}\right)}$$

where,

- ΔH = the heat of activation
- R = universal gas constant
- T1 - Tn = the temperature data points measured
- TK = Result in degrees Kelvin

You'll receive the final result in degree Celsius by doing a simple subtraction (TK – 273.15°K).

While calculating Mean Kinetic Temperature, it's important that:

• **Temperature sampling intervals be equal/regular** — You cannot afford to miss a reading. The actual interval will depend on your cold chain shipment's temperature excursion tolerance levels.

• **MKT segmentation be done effectively** — You need to measure fluctuations during different legs of the shipment's journey separately, particularly for segments like loading/unloading or packaging/unpackaging where excursions are more likely to occur.

• **Any temperature excursions must be thoroughly investigated** — A "safe" MKT result does not guarantee stability and safety. Any short-term spike needs to be analyzed, it could be indicative of larger problems.

The easiest way to get MKT is to use a temperature monitoring hardware/software to do the work for you.

The easiest ways aren't always the best though.

Why Measuring & Calculating Mean Kinetic Temperature with Data Logs/Loggers isn't the Best Strategy

Some of the latest and best cold chain temperature data loggers can record temperature, humidity, and pressure, providing convenient reports. Some even calculate the MKT for shipments in-transit.

There are, however, some issues with using data loggers to calculate mean kinetic temperature, issues such as:

1. Lack of additional in-depth information about the duration of temperature excursions, like where it happened and why.
2. Many low-cost data logger options only tell you if a preset temperature range was crossed. It doesn't tell you where that happened, or for how long.
3. Most data loggers commonly used today are single-use.
4. Lack of variable/adjustable measuring intervals, especially for the cold chain's riskiest legs — distribution and last-mile delivery.
5. Lack of additional parameters measured such as physical shock, light, oxygen, and phase change, which could be crucial variables for products like vaccine vials or volatile chemicals
6. Lack of reliability, because sudden spikes that irreparably damage a shipment could go undetected if the sampling intervals are high, or if the anomaly is ignored/normalized.
7. Lack of actionability, as most MKT values are calculated after a shipment is completed, which means you can detect spoilage, but it's too late to do anything about it.

Those last two issues — the inability to rely and react — are important.

Cut-throat competition and shrinking margins are making supply chain efficiency and throughput paramount. Product spoilage due to cold chain interruption is a growing concern, more so when you weigh the cost of loss and its liabilities.

You need more than just news that your shipment is damaged, you need it in time to be able to do something about it.

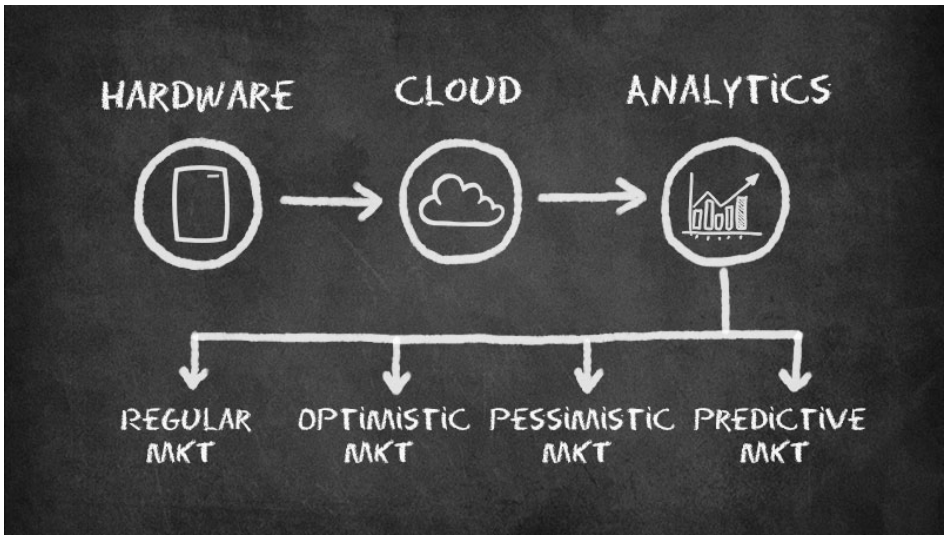
And that, is the real advantage of real-time cold chain temperature monitoring.

Why Should Mean Kinetic Temperature (MKT) be Calculated in Real-time?

Continuously monitoring data can give you a more meaningful MKT value; doing that in real-time can give you an edge.

It'll allow you to catch temperature spikes before they're "normalized", and it allows you to act before consecutive spikes do irreparable damage, allowing you to contain risk and manage contingencies better.

How to Calculate Mean Kinetic Temperature (MKT) in Real-time



1. **Use Good Hardware for Good Data Logging & Transmission**
   Use a reliable sensor/logger and stream data to an analytics platform. When there is no connectivity, there should be provisions to buffer the readings for transmission when possible, or better yet, persistent and redundant on-board storage.

Try and incorporate additional sensors — such as humidity, light, vibration — into your monitoring solution as well so you get a better picture of what is going wrong.

2. **Use the Cloud & Ensure Connectivity**
   Localized logging and analytics will be siloed, likely post-mortem, and rarely actionable. It's a better idea to stream active cold chain shipment temperature data to an online storage platform for easy access and analytics.

3. **Use the Right Analytical Approach**
   Temperature deviations in cold chain shipments could mean nothing, or everything. Make assumptions and arrangements for both.

Figure out the best way to interpret and act on anomalies in your MKT; it should depend on the sensitivity and type of your cold-chain shipment.

For example, imagine a situation where your device missed a reading. It could have been due to lack of connectivity, an abnormal hang-up, or something else that you don't have control over. You could interpret the gap in data by using one of these data models to predict the MKT accurately in such situations:

- **Regular MKT** – using the standard formula as a litmus test for shipment condition. This can only be calculated if all readings at a regular interval are available.

- **Optimistic MKT** - approaching spikes as deviant rather than disastrous, ideally to evaluate the condition of semi-perishable and somewhat inexpensive cargo (such as produce or fresh food) where minor damage or spoilage falls within acceptable limits. Optimistic MKT is achieved by interpolating any missing interval based on its previous and next value.

- **Pessimistic MKT** - approaching temperature spikes as disastrous rather than deviant, ideally to evaluate the condition of precious cargo that's very sensitive to temperature fluctuations (like pharma products or frozen meat) where even the slightest damage or spoilage is absolutely unacceptable, particularly when it could endanger lives. Pessimistic MKT is achieved by ignoring the complete sequence of data for the interval with missing data, switching instead to a different sampling interval that's unbroken.

  The upside to the pessimistic and optimistic approaches are that intervals, other than the one missed, aren't left out.

- **Predictive MKT** - evaluating whether spikes are deviant or disastrous to begin with, then gauging their impact on the future outcome of your cold chain cargo.

  This is by far the more reliable prediction, but it could also have inaccuracies due to data extrapolation.

To minimize the scope of error, it's best to analyze the values from regular, optimistic, pessimistic, and predictive MKT, and then determine what could be the most probable outcome.

How Will Real-time Mean Kinetic Temperature (MKT) Calculation Impact the Future of Cold Chain?

The ability to calculate MKT on the fly will be a game-changer for the cold chain.

By measuring the vitals of your shipment as it progresses, you can predict its outcome more accurately before it's too late, perhaps even do something to change that outcome.

Intelligent systems like these, especially when combined with real-time location and other sensors, can help you act instantly to salvage shipments that are in danger of damage beyond repair. The monitoring system itself could take control as well, automatically/proactively re-routing or activating damage control protocols for your cold chain logistics operations.

In case of temperature excursions, real-time MKT will proactively tell you the conditions that should be maintained for the rest of your shipment's journey to maximize its chance for survival.

Real-time MKT could help beyond just reducing spoilage and its associated costs.

From the QC manager monitoring temperatures fluctuations, to the Execs monitoring share price fluctuations, down to the customers monitoring quality fluctuations — improvements through real-time shipment temperature and condition monitoring are relevant to everyone in your supply chain.

See how much you can save with Real-time Mean Kinetic Temperature (MKT) monitoring using this Cold Chain Savings Calculator.

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